The Fluoridation of Drinking Water and Hip Fracture Hospitalization Rates in Two Canadian Communities

ABSTRACT

Objectives. The purpose of this study was to compare hip fracture hospitalization rates between a fluoridated and a non-fluoridated community in Alberta, Canada: Edmonton, which has had fluoridated drinking water since 1967, and Calgary, which considered fluoridation in 1991 but is currently revising this decision.

Methods. Case subjects were all individuals aged 45 years or older residing in Edmonton or Calgary who were admitted to hospitals in Alberta between January 1, 1981, and December 31, 1987, and who had a discharge diagnosis of hip fracture. Edmonton rates were compared with Calgary rates, with adjustment for age and sex using the Edmonton population as a standard.

Results. The hip fracture hospitalization rate for Edmonton from 1981 through 1987 was 2.77 per 1000 person-years. The age–sex standardized rate for Calgary was 2.78 per 1000 person-years. No statistically significant difference was observed in the overall rate, and only minor differences were observed within age and sex subgroups, with the Edmonton rates being higher in males.

Conclusions. These findings suggest that fluoridation of drinking water has no impact, neither beneficial nor deleterious, on the risk of hip fracture. (*Am J Public Health.* 1993;83:689–693)

Maria E. Suarez-Almazor, MD, PhD, Gordon Flowerdew, DSc, L. Duncan Saunders, MB, BCh, Colin L. Soskolne, PhD, and Anthony S. Russell, MD, FRCP

Introduction

Hip fractures are a major cause of morbidity, disability, and mortality in the elderly.[1] Initial reports suggested that sodium fluoride is an effective treatment for osteoporosis. However, recent studies have shown an increase in the risk of hip fracture after sodium fluoride therapy.[2–5] It has been hypothesized that the increase in bone mass caused by fluoride may be associated with an increase in bone fragility.[6]

Fluoridation of drinking water has been advocated for several decades as a universal and efficient way of decreasing dental caries, particularly in children.[7–10] Most health agencies recommend a fluoride level of 1 mg/L in drinking water. At this level, total dietary intake of fluoride in most individuals would be, at most, 2 to 3 mg/day,[11] substantially less than the daily dosages of fluoride received by patients with osteoporosis.[4] But the effects on the bone from fluoridated water ingested over several years (or decades) are still unclear. Initially, it was hypothesized that fluoridation could decrease osteoporosis and osteoporotic fractures; however, recent studies have reported a positive association between the risk of hip fracture and increasing levels of fluoride in drinking water.[12–17]

The purpose of this study was to compare the hip fracture hospital separation rates of two cities in the Canadian province of Alberta. Edmonton has had fluoridated drinking water since 1967 at levels of 1 mg/L. Natural fluoride levels in Calgary are, on average, about one third of Edmonton's levels. Calgary considered fluoridation in 1991 but this decision is currently under appeal. The two cities are fewer than 300 km apart. Traditionally, Calgary has been considered more of a white-collar city than Edmonton, with more service and administration jobs. Edmonton, the capital of the province, has more workers in the manufacturing and processing areas. These differences, however, appear to be relatively small, as shown in data from the 1986 Federal Census (Table 1).[18] Being in the same province and having similar size, these two cities provide a unique opportunity to compare health information, particularly because they offer the same access to health services through the Alberta Health Care Insurance Plan.

Methods

Data for this study were obtained from Alberta Health, the Alberta Bureau of Statistics, and Statistics Canada.

Selection of Cases

The province of Alberta has a universal health care system that provides health services to residents in the province, in accordance with the Canada Health Act. Admissions to all hospitals in the province are registered in the Alberta Health hospital morbidity file, which is computerized and includes the following variables: hospital; admission and discharge dates; pri-

The authors are with the Rheumatic Disease Unit, Department of Medicine, and the Department of Health Services Administration and Community Medicine, University of Alberta in Edmonton, Alberta, Canada.

Requests for reprints should be sent to Maria Suarez-Almazor, MD, Rheumatic Disease Unit, 562 Heritage Medical Research Center, University of Alberta, Edmonton, Alberta, Canada, T6G 2S2.

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TABLE 1—Demographic and Socioeconomic Characteristics of Edmonton and Calgary (1986 Federal Census)

	Edmonton	Calgary
Total population	573 980	636 105
Population density, per km^2	856.8	1189.4
Females, %	50.4	50.1
Married, %	47.3	49.0
Ethnicity, %		
Multiple origins	37.5	40.6
British	21.1	27.6
French	3.6	2.4
Ukranian	7.6	2.1
German or Dutch	8.3	7.8
Aboriginal	1.5	0.6
Chinese	3.6	3.5
Education, %[a]		
Less than grade 9	10.2	7.1
University degree	12.8	15.1
Income (1985)		
Average family income, $ (±SE)	40 465 ± 231	45 624 ± 250
Median family income, $	35 987	39 783
Low-income families, %	16.5	13.2
Low-income unattached individuals, %	38.3	34.2
Labor force, %		
Participation rate		
Men	81.4	84.0
Women	64.6	66.6
Unemployment rate		
Men	12.1	10.4
Women	9.7	9.8
Occupation, %[b]		
Manufacturing, construction and transportation		
Men	31.9	27.0
Women	3.7	3.1
Managerial, clerical, sales and other services		
Men	58.2	64.7
Women	94.1	94.6

[a]As a percentage of the population 15 and over.
[b]Sex-specific percentage of individuals employed in a particular occupational category.

mary, secondary, and tertiary discharge diagnoses; injury code (E-code); age; sex; and residence code. All discharge and injury diagnoses for hospitalizations between January 1, 1981, and December 31, 1987, were coded according to the *International Classification of Diseases, Ninth revision, Clinical Modification* (ICD-9-CM). We selected all admissions of persons aged 45 or older residing in the cities of Edmonton or Calgary between these dates who had a primary, secondary, or tertiary discharge diagnosis of hip fracture based on ICD-9-CM codes 820.0 to 820.9. All transfers to another hospital were excluded to avoid counting of the same hip fracture more than once. However, multiple admissions for the same fracture that were *not* transfers to other hospitals could not be identified and therefore were included in the total number of hospitalizations. None of the included hospitalizations had a discharge diagnosis code of 905.3 (late effects of hip fracture) or 733.8 (complications of previous fractures).

Population Estimates

Midyear population estimates for each year were obtained from the Alberta Bureau of Statistics and tabulated according to sex and to the following age groups: 45 to 64 and 65+. To calculate population estimates by 5-year age groups, we used the age–sex distributions for Edmonton and Calgary from the 1981 and 1986 federal censuses provided by Statistics Canada, and then we applied linear interpolation (1982 to 1985) and linear extrapolation (1987) to calculate population estimates for the other years.

Hospital Admission Rates for Hip Fracture

Hospital admission rates were calculated for 1981 to 1987 for the age groups 45 to 64 and 65+, using the sum of the midyear populations from 1981 to 1987 (person-years) and the total numbers of admissions with a discharge diagnosis of hip fracture.

Age–sex standardized admission rates were calculated for Calgary using the direct method of standardization with 5-year age groups. The standardized rates were calculated by applying the age–sex specific Calgary rates to the Edmonton standard population. Standardized rates were obtained for the total Calgary population aged 45 and over, for each sex, and for each of the age subgroups: 45 to 64 and 65+ years.

To calculate the statistical significance of the differences between the Edmonton rate and the Calgary age-sex standardized rate, a *z* test was used. This test uses the variance of the difference observed for each age–sex specific rate to estimate the overall variance of the difference between standardized rates.[19] Approximate 95% confidence intervals for the rate ratios (RR) were based on the variance approximation: var (log RR) = $1/n_1 + 1/n_2$, where n_1 and n_2 are the numbers of hip fracture hospitalizations in the two cities. This leads to the approximate confidence limits: exp [log RR ± $1.96\sqrt{(1/n_1 + 1/n_2)}$].

Results

From 1981 to 1987, in the population aged 45 and over, there were 2667 admissions in Edmonton and 2600 in Calgary with a primary, secondary, or tertiary diagnosis of hip fracture. Of these, 2486 (93.2%) in Edmonton and 2429 (93.4%) in Calgary had hip fracture as the primary diagnosis. Admission rates for the age groups 45 to 64 and 65+ are shown in Table 2; standardized rates and rate ratios in Edmonton and Calgary for different age-sex subgroups are given in Table 3. The crude hip fracture admission rate for Edmonton from 1981 to 1987 was 2.77 per 1000 person-years, compared with an age–sex standardized Calgary rate of 2.78 per 1000 person-years. No statistically significant differences were observed in the rates for women or for both sexes combined. However, for all men aged 45+ and the subgroup of men aged 65+, the differences between the Edmonton and Calgary standardized rates were statistically significant (RRs of 1.12 and 1.13, respectively).

The distribution of external causes of hip fracture injury is shown in Table 4. Ninety-three percent of hip fractures in Edmonton and 92% of those in Calgary were associated with an accidental fall.

Standardized rates and rate ratios were also calculated including only admissions with a primary discharge diagnosis of hip fracture. No major differences were observed when these data were compared with the results obtained by including all hospitalizations with a primary, secondary, or tertiary diagnosis.

TABLE 2—Hospitalization Rates for Hip Fracture in Edmonton and Calgary, 1981 through 1987, by Age and Sex

	Edmonton			Calgary		
	Person-Years 1981–1987	No. Cases	Rate[a]	Person-Years 1981–1987	No. Cases	Rate[a]
Men						
45–64	331 297	195	0.59	340 331	181	0.53
65+	124 205	632	5.09	116 118	519	4.47
Women						
45–64	336 423	201	0.60	339 099	231	0.68
65+	171 833	1639	9.54	165 486	1669	10.09

[a]Number of admissions per 1000 person-years.

TABLE 3—Standardized Hip Fracture Admission Rates and Rate Ratios for Edmonton and Calgary, 1981 through 1987[a]

	Edmonton[b] Crude Rates	Standardized[b] Calgary Rates	Rate Ratio	Approximate 95% Confidence Intervals
Men				
45–64	0.59	0.55	1.07	0.87, 1.32
65+	5.09	4.52	1.13	1.00, 1.27
Total 45+	1.82	1.63	1.12	1.01, 1.24
Women				
45–64	0.60	0.71	0.85	0.70, 1.03
65+	9.54	9.91	0.96	0.90, 1.03
Total 45+	3.62	3.82	0.95	0.89, 1.01
Both sexes				
45–64	0.59	0.63	0.94	0.82, 1.08
65+	7.67	7.65	1.00	0.94, 1.06
Total 45+	2.77	2.78	1.00	0.95, 1.06

[a]Using Edmonton as a standard population.
[b]Rate per 1000 person-years.

TABLE 4—External Causes of Hip Fracture Injury[a]

	Edmonton		Calgary	
	No.	%	No.	%
Transport accidents (E800–E849)	72	2.7	67	2.6
Accidental falls (E880–E888)	2479	93.0	2392	92.0
Homicides, injuries by others (E960–E968)	9	0.3	8	0.3
Other	76	2.8	85	3.3
Missing codes	31	1.2	48	1.8
Total	2667	100	2600	100

[a]Based on E codes from the *International Classification of Diseases, Ninth Revision, Clinical Modification.*

Discussion

Fluoride was first introduced into North American drinking water in Grand Rapids, Michigan, in 1945,[20] and since then it has been a source of controversy. The 1991 Public Health Service report on fluoride benefits and risks from the US Department of Health and Human Services[21] supports the fluoridation of drinking water at 1 mg/L. Recent publications, however, have suggested that the risk of hip fracture increases with the concentration of fluoride in drinking water.[12–17] Furthermore, therapy for osteoporosis with sodium fluoride has also been associated with an increase in some fractures, including fractures of the hip.[2–5]

We sought to compare the hospital admission rates for hip fracture in a fluoridated community with those of a nonfluoridated community. We chose Edmonton and Calgary because of their similarities in aspects other than fluoridation and because Edmontonians have been drinking fluoridated water for more than 2 decades, which we consider a substantial length of exposure. No significant difference was observed in the overall rate between the two cities. Although the increase in Edmonton rates for men achieved statistical significance, the differences were small and probably not relevant. It is well recognized that large population studies such as this one often show statistical significance when the differences are quite small and not clinically important.[19] Moreover, while strong associations may provide a basis for causal inference, weak associations are often secondary to confounding effects.[22] The increased risk observed in men was small when compared with the risks seen from other etiologic agents. Furthermore, when men and women were considered together, no statistically significant differences were observed in any of the age groups even though the sample size was increased. This suggests that the overall risk for the population is not increased.

We were unable to exclude repeat hospitalizations for the same fracture because of the lack of record linkage in the Alberta Health Care files, so only transfers were excluded. Nevertheless, it is unlikely that there were differential patterns of readmission between the cities, particularly since the distribution of hip fractures according to primary, secondary, and tertiary diagnosis was similar in both. Persons with previous hip fracture were not excluded from the calculations of person-years at risk. Since the incidence of hip fracture is relatively low in relation to the total population at risk, the effect of including individuals with a previous hip fracture in the denominator is likely to be negligible.

The proportion of fractures associated with accidental falls was similar in the two cities, which indirectly suggests a comparable risk of falling. Risk factors for osteoporosis, such as estrogen therapy, body build, and alcohol and tobacco use, are also likely to be similar enough because both cities are in the same province, fewer than 300 km apart, and have similar size, ethnic composition, and access to health services. There are some minor differences in the socioeconomic status and occupation of their residents, with Edmonton being more of a blue-collar city than Calgary. However, the impact of all these variables on the incidence of hip fracture is unknown. A recent study of US counties showed an association between poverty levels and hip fracture rates.[14] We could speculate that socioeconomic status may be related to certain risk factors such as diet, alcoholism, or estrogen prophylaxis. On the other hand, manual labor may increase bone mass and have a protective effect. It is unlikely, however, that socioeconomic status alone would mask a potential effect of fluoridation because the differences between the two cities are relatively small (Table 1). Calcium levels in drinking water range approximately from 25 to 35 mg/L in Edmonton and from 50 to 60 mg/L in Calgary (National Water Quality Data Bank System, Alberta Environment). Although calcium consumption appears to have a protective effect on the risk of osteoporosis[1,23] and it has been suggested that soft water increases the risk of fracture,[14] it seems unlikely that the small amounts would have a major effect. The lower concentration of calcium in Edmonton would then, if anything, increase the risk of fractures in that city rather than counteract a potential increase from fluoridation.

Fluoride therapy for osteoporosis has been advocated during the past 2 decades.[24] Sodium fluoride stimulates bone formation through a positive effect on osteoblastic activity. It is deposited in the bone as fluoroapatite crystals, replacing hydroxyl ions with fluoride ions.[25] The resulting bone matrix may not be adequately mineralized, resulting in osteomalacia.[24,25] Approximately 10% of patients receiving sodium fluoride for treatment of osteoporosis develop acute pain in the lower limbs from stress microfractures.[26-28] Although vertebral fracture rates have been shown to decrease in randomized trials,[24] several studies have suggested that the incidence of fractures at other sites may be increased.[2-5] Patients with renal disease may also be at higher risk because of decreased renal excretion of fluoride.[25,29] Nevertheless, sodium fluoride as a therapy for osteoporosis is used in a dosage ranging from 40 to 100 mg daily—substantially more than the 2- to 3-mg daily amount ingested through dietary intake in fluoridated areas.[11]

Studies in the 1950s and 1960s suggested an increase in radiological bone density in individuals living in areas with artificial or high natural fluoride levels.[30-35] Those studies, which reported fracture rates, generally failed to show a significant effect in any direction. Bernstein et al.[33] reported a higher proportion of women with collapsed vertebra in a low-fluoride area in North Dakota. Yet, contrary to current knowledge, the prevalence of collapsed vertebra was higher in men than in women, implying that the sample did not truly represent the population at risk. The National Health Interview Survey (1973 to 1977), involving 44 031 respondents, showed a 9% increase in reported hip fracture hospitalizations in women from high-fluoride areas and a 10% increase in men from low-fluoride areas, but neither difference was statistically significant.[36] Simonen and Laitinen[37] compared the incidence of hip fractures (1967 to 1978) in the population aged 50 and over of two Finnish towns: Kuopio with fluoridated water since 1959 and Jyvaskyla with only trace amounts. Sex-age specific rates were significantly higher in the nonfluoridated community, suggesting a protective effect of fluoridation. However, another Finnish study published a year later[38] also compared the incidence of hip fractures, this time in three areas of Finland with different fluoride concentrations. The fluoridated area was the city of Kuopio, as in the previous study, but on this occasion, no significant differences were observed. Sowers et al.[12,13] reported that women in a high-fluoride area (4 mg/L) had a 2.2-fold risk of fractures compared with those in the control area (1 mg/L). In this case, however, the low-fluoride area was itself a community with artificial fluoridation.

It is noteworthy that the more recent studies have reported a positive association between fluoride levels and hip fracture rates. Jacobsen et al.[14] reported the geographic distribution of hip fracture incidence rates in White women, 65 years and older, in the United States at the county level; after controlling for other factors, they observed a positive correlation between the proportion of the population with fluoridated water and age-adjusted rates. In a recent updated report involving a study of 129 counties across the United States,[17] these authors again found a positive association between fluoridation and hip fracture rates. The boundaries of the counties, however, rarely coincided with those of public water systems. The relative risks were small (1.08 for women, 1.17 for men) but were unexpectedly highest for those communities with recently fluoridated water supplies (less than 5 years). Cooper et al.[15,16] also compared fluoride levels and the incidence of hip fracture in 39 counties in England and Wales. Although their initial analysis did not show a significant correlation, a reanalysis of the data using least squares analysis weighted by population size gave a positive correlation between the level of fluoride in drinking water and hip fractures.

Both the American and British studies were based on rates from several counties in large geographic areas, which may vary in many respects. The impact on these ecological studies of confounding factors not included in the analysis is unknown. However, because the cities of Edmonton and Calgary are in proximity and are comparable in many ways, it seems unlikely that the differences between them would "mask" a potential relationship between fluoride levels in drinking water and hip fracture rates.

Concerns on the potential carcinogenetic effects of fluoride led to a study of fluoride and cancer by the US National Cancer Institute. Initial results suggested an increase in osteosarcoma rates in male rats exposed to the highest levels of fluoride.[39] The final results, however, were unconclusive because major biases attributed to diet and subsequent mortality in the rats had occurred. For this reason, the study was redesigned and repeated with negative results.[40] A recent report compared the incidence rates of osteosarcoma in Edmonton with those in Calgary and observed no significant differences.[41]

The design of this study had limitations related to the ability to control for other relevant factors. Ingestion from other sources, such as dentifrice or mouth rinses, may increase the total daily intake of fluoride. Yet ingestion from these sources occurs mostly in children and appears to be negligible in adults.[11,42,43] This study did not attempt to address the effects of length of residency in the communities. Data from the 1986 Federal Census show that approximately 20% of the population of Edmonton and 22% of the population of Calgary were residing either at a different census subdivision or outside Canada 5 years earlier.[18] These proportions, however, are based on the population 5 years old and over; age-adjusted results for the province of Alberta show that only 12% of the 45- to 64-year-old individuals and 9% of those aged 65 and over were residing at a different location 5 years earlier. The effect of migration may reduce differences in exposure between the two cities and real differences in hip fracture rates, if such differences truly exist. This effect, however, is probably small given the low proportion of migrants in the age groups at increased risk.

It would appear from the published data that the effect of fluoridation on osteoporotic fractures remains unresolved. In general, the majority of the studies are old, and so the exposure to fluoride was short. In most cases, no statistically significant effects were observed, but this could be partly attributed to small samples and low statistical power. The present study, which compared two large communities, had 95% statistical power to detect a difference of 10% in the overall group and 85% power to detect that same difference in the high-risk group of women aged 65+ (two-tailed test at a level of significance $\alpha = .05$). Although a statistically significant increase in the risk of hip fracture was observed among Edmonton men, this increase was relatively small (RR = 1.12). No statistically significant differences were found between the two cities for the population as a whole, or in either age group studied when men and women were considered together. In conclusion, the results of this study suggest that fluoridation of drinking water has no major impact, beneficial or deleterious, on the risk of hip fracture. □

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